ABSTRACT

Microgravity Science in the U.S.A. involves research in fluids science, combustion science, materials science, biotechnology and fundamental physics. The purpose is to achieve a thorough understanding of the effects of gravitational body forces on physical phenomena relevant to those disciplines. This includes the study of phenomena which are usually overwhelmed by the presence of gravitational body forces and, therefore, chiefly manifested when gravitational forces are weak. In the pragmatic sense, the research involves gravity level as an experimental parameter.

Calendar year 1992 is a landmark year for research opportunities in low earth orbit for Microgravity Science. For the first time ever, three Spacelab flights will fly in a single year. IML-1 was launched on January 22; USML-1 was launched on June 25; and, in September, SL-J will be launched. A separate flight involving two cargo bay carriers, USMP-1, will be launched in October. From the beginning of 1993 up to and including the Space Station era (1997), nine flights involving either Spacelab or USMP carriers will be flown. This will be augmented by a number of middeck payloads and get away specials flying on various flights.

All of this activity sets the stage for experimentation on Space Station Freedom. Beginning in 1997, experiments in Microgravity Science will be conducted on Station. Facilities for doing experiments in protein crystal growth, solidification and biotechnology will all be available. These will be joined by middeck-class payloads and the microgravity glove box for conducting additional experiments. In 1998, a new generation protein crystal growth facility and a facility for conducting combustion research will arrive. A fluids science facility and additional capability for conducting research in solidification, as well as an ability to handle small payloads on a quick response basis, will be added in 1999. The year 2000 will see upgrades in the protein crystal growth and fluids science facilities. From the beginning of 1997 to the fall of 1999 (the “man-tended capability” era), there will be two or three utilization flights per year. Plans call for operations in Microgravity Science during utilization flights and between utilization flights. Experiments conducted during utilization flights will characteristically require crew interaction, short duration and less sensitivity to perturbations in the acceleration environment. Operations between utilization flights will involve experiments that can be controlled remotely and/or can be automated. Typically, the experiments will require long times and a pristine environment. Beyond the fall of 1999 (the “permanently-manned capability” era), some payloads will require crew interaction; others will be automated and will make use of telescience.
NASA Headquarters
Office of Space Science and Applications
Microgravity Science and Applications Division

Microgravity Science and Applications Division
Research Objectives, Opportunities, and Facilities

Presented to:
Space Station Freedom Utilization Conference
August 3 - 6, 1992
Huntsville, Alabama

Robert J. Bayuzick
Program Goal

Develop a comprehensive research program in fluids science, combustion science, materials science, biotechnology, and fundamental physics for the purpose of attaining a structured understanding of gravity-dependent physical phenomena and those physical phenomena made obscure by the effects of gravity.

Fluid Dynamics and Transport Phenomena
Research Areas

- Multiphase flow and heat transfer
- Suspension/colloid/granular media mechanics
- Solid-fluid interface dynamics
- Capillary phenomena
- Magneto/electrohydrodynamics
- Transport phenomena
Combustion Science Research Areas

- Ignition, smolder, solid materials
- Gaseous diffusion flames
- Gaseous premixed flames
- Heterogeneous (particles and droplets)
- Metals and combustion synthesis

Materials Science Research Areas

- Electronic and Photonic Materials
- Metals and Alloys
- Glasses and Ceramics

or

- Crystal Growth
- Solidification Fundamentals
- Thermophysical Properties
Biotechnology Research Areas

- Cell physiology
- Cell differentiation
- Protein crystal growth
- Biological separations

Fundamental Physics Research Areas

- Critical point phenomena
- Gravitational physics
FLIGHT OPPORTUNITIES -- THE PRESENT

- Four MSAD missions in CY92:
  - IML-1: successful mission: January 22 - 30, 1992
  - USML-1: successful mission: June 25 - July 9, 1992
  - Spacelab-J
  - USMP-1
# International Microgravity Laboratory (IML-1)
## Microgravity Science and Applications Experiments

<table>
<thead>
<tr>
<th>Apparatus/Experiment</th>
<th>Acronym</th>
<th>Principal Investigator</th>
<th>Country of Origin</th>
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<tr>
<td>Fluids Experiment System</td>
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<td>U.S.A.</td>
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<td>- Casting and Solidification Technology</td>
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<td>Dr. L. van den Berg</td>
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<td>VCGS</td>
<td>Dr. R. Cadoret</td>
<td>France</td>
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<td>Dr. Kanbayashi</td>
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<td>Dr. G. Wagner</td>
<td>Germany</td>
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# U.S. Microgravity Laboratory (USML-1)
## Microgravity Science and Applications Experiments

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<td>- Orbital Processing of High Quality Cd-Te</td>
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<td>Drop Physics Module (DPM)</td>
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<td>- Science and Technology of Surface Controlled Phenomena</td>
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<td>- Drop Dynamics Investigation</td>
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<td>S. Ostrach</td>
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### Spacelab J (SL-J)
#### Microgravity Science Experiments

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### U.S. Microgravity Payload (USMP-1)
#### Microgravity Science and Applications Experiments

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Microgravity Science and Applications Division Baseline Plan: 1994 - 2004

### Fundamental Science
- Condensed Matter Physics
  - Lambda Point Experiment
  - Critical Fluid Light Scattering Experiment
  - Critical Fluid Viscosity Measurement Experiment
  - Low Temperature Research Facility
  - Satellite Test of Equivalence Principle

- Fluids & Transport Phenomena
  - Surface Tension Driven Convection Experiment
  - Drop Physics Module
  - Critical Point Facility
  - Bubbles, Drops, and Particle Unit
  - Geophysical Fluid Flow Cell
  - Mechanics of Granular Materials
  - Advanced Fluids Microblocks
  - Advanced Fluids Module
  - Fluid Physics/Dynamics Facility
  - Modulator Contamination Processing Facility
  - Combustion Science
    - Solid Surface Combustion Experiment
    - Advanced Combustion Microblocks
    - Advanced Combustion Module
    - Modulator Combustion Facility

### Materials Science
- Metals and Alloys
- Glasses and Ceramics
- Electronic & Photonic Materials
- Crystal Growth Furnaces
  - MEPHISTO (F)
  - Advanced Protein Crystal Growth
  - Advanced Protein Crystal Growth

### Biotechnology
- RAMSES (F)
  - Detailed Supplemental Objectives
  - Bioreactor Biotechnology Facility

### Microgravity Science and Applications Division Planning Manifest

<table>
<thead>
<tr>
<th>CY91</th>
<th>CY92</th>
<th>CY93</th>
<th>CY94</th>
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**NOTES:**
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- (U) Indicates U.S. non-MSAD hardware in which MSAD Investigators are flying
- *Indicates enhanced/upgraded version
-  Will not fly if Space Station is available
- **Candidate transition hardware**

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-  Will not fly if Space Station is available
- **Candidate transition hardware**
## Microgravity Science and Applications Division Planning Manifest

### CY96
- **USML-3**
  - (STS-____)
  - **LRD - 9/17**
- **STCCE+**
- **APGC**
- **CGF**
- **SAMS**
- **GBX**
- **DCE**

### CY97
- **USMP-5**
  - (STS-97)
  - **LRD - 3/18/98**
- **IDGE+**
- **APGC**
- **CGF**
- **SAMS**
- **AADS P-A2**

### CY98
- **USMP-6**
  - (STS-____)
  - **LRD - 4/22/99**
- **SAMS**
- **AADS P-A1**

### CY99
- **USMP-7**
  - (STS-____)
  - **LRD - 6/22/99**
- **MIDDECK**
- **OR GAS**
- **LD - 6/22/99**
- **PCG-II-2**
- **SAMS**

### CY00
- **USMP-8**
  - (STS-____)
  - **LRD - 11/21/99**
- **AADS P-A2**
- **SAMS**
- **SAMS**
- **SAMS**
- **SAMS**

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## Microgravity Science and Applications Division Planning Manifest

### CY91
- **MIDDECK**
- **OR GAS**
- **LD - 4/22/91**
- **PCG-III-5**
- **SAMS**

### CY92
- **MIDDECK**
- **OR GAS**
- **LD - 5/3/91**
- **PCG-I-1**
- **SAMS**

### CY93
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- **OR GAS**
- **LD - 6/3/91**
- **PCG-I-1**
- **SAMS**

### CY94
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- **OR GAS**
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### CY95
- **MIDDECK**
- **OR GAS**
- **LD - 8/3/91**
- **PCG-I-1**
- **SAMS**

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### CHARTS
- **Cell Cult DSO (I)**
- **APGC (4/yr)**
- **APGC (I)**
- **Coop Prog. (1/yr)**
- **PBE (GAS)**
- **MIDDECK**
- **OR GAS**
- **LD - 9/5/91**
- **PCG-III-5**
- **SAMS**

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### FREEFLYER
- **PBE (GAS)**
- **Spacehab-2**
- **STS-60**
- **LRD - 10/21/93**
- **SAMS**
- **LD - 11/24/91**
- **Cell Cult DSO**
- **LRD - 6/22/93**
- **Cell Cult DSO**
- **SAMS**
- **LRD - 11/2/93**
- **EURECA-2L (I)**
- **Coop Prog.**

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Microgravity Science and Applications Division

Planning Manifest

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SSAMS (4/yr) SAMS (2/yr) DCE PMZF PMZF (2/yr)
PACG (4/yr) APCG (3/yr) PMZF PMZF (2/yr)
Coop. Prog. (2/yr)

(FSTS__) MGM SAMS

SSAMS (4/yr) SAMS (2/yr) DCE PMZF PMZF (2/yr)
PACG (4/yr) APCG (3/yr) PMZF PMZF (2/yr)
Coop. Prog. (2/yr)

FREEFLYER FREEFLYER FREEFLYER FREEFLYER FREEFLYER

(FSTS__) EURECA-3L (I) Coop. Prog.

FSFF STEP

FREEFLYER FREEFLYER FREEFLYER FREEFLYER FREEFLYER

(FSTS__) EURECA-3L (I) Coop. Prog.

FSFF STEP

Microgravity Science and Applications Division

Planned Research Announcements

Calendar Year:

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Combustion Science

Biotechnology

Fluids and Transport

Materials Science

Fundamental Science

Ground-Based Research

Combustion

Biotechnology

Fluids and Transport

Materials Science

Fundamental
Microgravity Science and Applications
Division FY92 Budget by Program

- Science: $1,995K
- Biotechnology: $2,183K
- Protein Crystal Growth (PCG): $4,761K
- Containerless: $14,908K
- Advanced Technology Development (ATD): $1,870K
- HQ & Center Support: $26,596K
- Research and Analysis (R & A): $16,600K
- Solidification: $21,025K
- Fluids: $9,658K
- Combustion: $6,810K
- Fundamental Science: $9,147K

Total: $120,800K
Integrated Launch Schedule

Overall Flight Sequence

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Utilization Flight Increment

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MSAD Space Station Payload Traffic Model (April 1992)

### CY 1997

- Protein Crystal Growth
- Solidification Research
- Fluids & Combustion
- Containerless Processing
- Small & Rapid Response
- Middeck-Class Payloads with SAMS SSF *
- Biotechnology
- SSF-Provided Microgravity Glovebox

### CY 1998

- APCG
- SSSP
- Comb
- FPDF
- MCF
- MCPF
- MDC
- MGBX
- SAMS
- BTF
- C
- M

### CY 1999

- APCG
- SSSP
- Comb
- FPDF
- MCF
- MCPF
- MDC
- MGBX
- SAMS
- BTF
- C
- M

### CY 2000

- APCG
- SSSP
- Comb
- FPDF
- MCF
- MCPF
- MDC
- MGBX
- SAMS
- BTF
- C
- M

* SAMS SSF is Station unique hardware, not transition hardware

**Legend:**
- Returned Hardware
- Space Station Unique Hardware
- Transition Hardware (Assume MPE/Interface Adapter provided by SSF)
- Evaluate the effects of gravity on the growth of protein crystals
- Study physics/dynamics of macromolecular crystal growth
- Support biotechnology research by growing high quality macromolecular protein crystals which can be used for x-ray crystallography

Protein Crystal Growth Program Evolution

PCG (current)
Protein Crystal Growth
Middeck Refrigerator/Incubator Module with Vapor Diffusion Apparatus

APCG (1993 - 1997)
Advanced Protein Crystal Growth
Middeck using Thermal Enclosure System (TES) for PI-specific crystal growth hardware

APCG transition (1997)
TES units modified for flight in SSF

APCGF (1998 - 2000)
Advanced Protein Crystal Growth Facility for SSF
Host Facility for Advanced Thermal Enclosures, PI-specific Crystal Growth Hardware
Advanced Protein Crystal Growth (APCG)
Payload Description (1997 - 1998)

- Power 0.5 kW nominal/1 kW peak
- Mass 300 kg
- Volume 1 rack

TRANSITION HARDWARE
2 Thermal Enclosure System (TES) units with crystal growth apparatus
SSFP provides adapter hardware, integration

- APCG plans to accommodate second generation crystal growth hardware in TES units
  - Vapor Diffusion Apparatus
  - Thermally-controlled batch process
  - Liquid-liquid diffusion
  - Dynamically-controlled systems
- Automated experiment initiation and deactivation


- Power 2.1 kW nominal/2.4 kW peak
- Mass 616 kg
- Volume 1 rack

Space Station-unique hardware
Advanced thermal enclosures
Enhanced diagnostic systems with imaging capability

- Third generation protein crystal growth hardware
  - May accommodate a larger number of experiments than APCG by using advanced thermal enclosures
  - Can accommodate current TES, new thermal enclosures, or PI-supplied thermal enclosures for long-duration crystal growth, and enhanced diagnostics
  - Automated experiment initiation and deactivation
- Gain understanding of the mechanisms which correlate directional solidification parameters and materials properties for various technologically important materials

- Explore potential for utilization of low gravity environment to develop unique materials or materials structures which have unique, crafted properties

- Measure thermophysical properties of materials
Space Station Furnace Facility/Crystal Growth
Furnace Payload Description
(1997 - 1998)

- **Power**
  - 2.0 kW nominal/4.0 kW peak
- **Mass**
  - 1050 kg
- **Volume**
  - 2 racks
  1 Rack - Core: Space Station-unique controls, power conditioning and diagnostics
  1 Rack: CGF furnace
    - Pressure vessel with flexible glovebox
    - Reconfigurable furnace module
    - Furnace translation mechanism
    - Automated sample exchange mechanism (up to six samples)

- Gradient zone thickness can be optimized before launch, and a heat extraction plate can be included to obtain steeper gradients
- Interface demarcation will be available by mechanical and current pulsing

Space Station Furnace Facility (SSFF)

- **Power**
  - 6.5 kW nominal/9.0 kW peak
- **Mass**
  - 1,350 kg
- **Volume**
  - 3 racks
  1 Rack - Core: Space Station-unique controls, power conditioning and diagnostics
  1 Rack: Furnace Module 1
  1 Rack: Furnace Module 2

- Furnace Modules -- to be determined from NASA Research Announcement/Announcement for Opportunity (NRA/AO) selection -- first PI selections in August 1992
- Modules being considered
  - Upgraded programmable Multi-Zone Furnace (used for planning purposes)
  - Transparent Furnace
  - Bridgman with Quench
  - Float-Zone Crystal Growth Furnace

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• Provide better understanding of fundamental theories of combustion processes and phenomena, such as:
  - Premixed gaseous fuel combustion
  - Laminar and turbulent diffusion flames
  - Flame spreading and smoldering with solid fuels
  - Flame spreading over liquid pools
  - Effectiveness of fire extinguishing techniques
  - Droplet, particle, and spray combustion
  - Metals combustion

• Provide scientific and engineering data for a variety of combustion related applications, such as spacecraft fire safety
Advanced Combustion Middeck Payload

- **Power**: 120 W
- **Mass**: 400 kg
- **Volume**: 4 middeck lockers

- A CoDR was held in December 1991
- Will have the capability to do multiple experiment samples intensified video for low luminosity
- Studying the capability for chamber atmosphere clean-up

Modular Combustion Facility (MCF)
Payload Description (1998 - 2000)

- **Power**: 1.5 kW nominal/2.3 kW peak
- **Mass**: 1,400 kg
- **Volume**: 2 racks

**TRANSITION HARDWARE**

- **1 Rack - Core**: Shares a common core with the fluids module
- **1 Rack Module 1 - Combustion experiment rack**

- The combustion experiment rack will house a generic combustion chamber with investigation-specific equipment:
  - Nozzles for burning of gases
  - Sample holders for solid fuels experiment

- The combustion chamber will have ports to accommodate different modular diagnostics systems:
  - CCD video system
  - Infrared imager
  - Schlieren imaging system
  - Temperature measuring probes
  - Gas sampling probes
Modular Combustion Facility (MCF)
Payload Description (2001+)

- Power 5 kW nominal/7.1 kW peak
- Mass 1,400 kg
- Volume 2 racks

STATION-UNIQUE HARDWARE
1 Rack - Core Core 2 shared with fluid modules
1 Rack Module 2 - combustion experiment rack

- Module 2 to be determined from NRA/AO selection
- Two candidate experiment racks under study
  - Quiescent Combustion Chamber
  - Low-Speed Combustion Tunnel

Fluid Physics and Dynamics
Science Utilization

- Provide advances in theories of fluid physics
- Provide improvements in thermophysical property measurement
- Provide scientific and engineering data related to fluids-related applications and systems
- Experiments may cover a broad area of interest:
  - Isothermal-isosolutal capillary phenomena
  - Capillary phenomena with thermal/solutal gradients
  - Thermal solutal convection and diffusive flows
  - First order phase transitions in a static fluid
  - Multi-phase flow
Fluids Program Evolution

**Fluid Experiment System (1985, 1992)**
- Fluid Experiment System
- Spacelab, multi-user

- Surface Tension
- Driven Convection Experiment
- Spacelab, PI-specific

- Pool Boiling Experiment
- Get away special payload, PI-specific

**AEM (1999)**
- Advanced Fluids Module for SSF
- Multi-user module added to Fluids/Combustion core facility

Fluid Physics Dynamics Facility (FPDF) Payload Description (1999+)

- **Power**
  - Fluids Module 1: 2.0 kW nominal/3.0 kW peak
  - Fluids Module 2: 5.9 kW nominal/9.5 kW peak

- **Mass**
  - 700 kg

- **Volume**
  - 1 rack

Core shared with MCF

1 Rack
- Fluids Module-1 (1999)
- Changed out for Fluids Module-2 (2000)

- Modules 1 and 2 -- to be determined by AO/NRA selection

- Two candidate experiment racks under study
  - Support dynamic fluid experiments in a multi-phase apparatus
  - Vibration isolation containment enclosure for sealed-cell experiments

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- Accommodate experiments requiring the positioning and manipulation of materials without physical contact with container walls

- Conduct research on properties and phenomena that on Earth are seriously affected by container contamination, container-generated nucleations, and gravity effects
Modular Containerless Processing Facility (MCPF) Payload Description (under review)

- Power: 2.5 kW nominal/3.0 kW peak
- Mass: 700 kg
- Volume: 1 rack

Sample positioning devices
Diagnostics and control

- Levitation modules to position the sample may be electrostatic, electromagnetic, acoustic fields, or a hybrid combination
- Gain understanding in vast area of physical sciences ranging from the behavior of liquid drops in space, the measurement of thermophysical properties of materials, and the characterization of metals, glasses, and ceramics heated to temperatures up to 2700°C

Biotechnology Science Utilization

- Study cell function and differentiation in a low mechanical stress environment
- Culture end-differentiated tissue models for studies of genetic regulations
Biotechnology Program Evolution

**Isoelectric Focusing**
- 1994, 1995
- Middeck, PI-specific

**Phase Partitioning**
- 1992, 1993
- Middeck, PI-specific

**Continuous Flow Electrophoresis System**
- 1982-1985

**Bioraactor**
- DSO in 1991
- Future flights TBD
- Rotating wall cell culturing system
- Middeck, multi-user
- Awaiting results of 1991 Biotechnology NRA to determine future flight development

**Biotechnology Facility for SSF**
- Host facility for future investigations in:
  - Cell culturing
  - Cell separations
  - Future areas of Biotechnology

---

**Biotechnology Facility Payload Description (1997+)**

- **Power**
  - TBD kW nominal and peak

- **Mass**
  - 700 kg

- **Data**
  - TBD Kbits/sec

- **Volume**
  - 1 rack

- The BTF will accommodate a series of PI-developed, self-contained biotechnology experiments. BTF "services" will include power conditioning and distribution, video and data processing, and basic gases and fluids.

- Concept may serve as the basis for a Small and Rapid-Response (SRR) Payload (1999)
"Middeck Class"
Payloads (1997+)

- Power: TBD kW nominal and peak
- Mass: TBD
- Data: TBD Kbits/sec
- Volume: 2 racks

**TRANSITION HARDWARE**
Middeck-class experiments
SSFP provides adapter hardware, integration

- The SSFP-provided Middeck Class Payload Adapter (MDC) will host a series of small to moderate-scale microgravity experiments by providing an interface that emulates the Shuttle middeck.
  - Experiments in Fluids and Transport Phenomena, Combustion, Materials Science
- MDC Accommodations will be similar to those provided by the SSFP interface hardware used for the APCG Transition Payload

**SSFP-Provided Microgravity Glovebox** (1997+)

- Power: TBD kW nominal and peak
- Mass: 700 kg
- Data: TBD Kbits/sec
- Volume: 1 rack

- The SSFP-Provided Materials Science Glovebox (MSG) provides an enclosed work space isolated from the SSF ambient environment for handling microgravity science samples and hardware.
- The MSG will accommodate a series of small-scale microgravity science experiments and technology demonstrations.
- MSG services will include video and film cameras with appropriate lighting, temperature control and heat rejection in the work volume, power outlets for use by experiments and apparatus for recovering fluid spills.
Utilization Flights

- All Microgravity Science and Applications Division (MSAD) payloads plan to operate during utilization flights
- Some operations will be very similar to Spacelab
  - High-speed film cameras for data storage
  - Discipline-emphasis crew skills
- Operations unlike Spacelab
  - On-orbit rack changeout
  - Logistics/resupply (gases), sample harvesting, and changeout for return
  - Experiment set up for ground-tended runs

Unmanned Operations

- All MSAD payloads except combustion plan to operate during ground-tended operations
- Payloads will require uplink communications
  - For initiating run sequences
  - Power on/off
  - Restart experiment run
- Payloads will require downlink
  - Monitoring experiment runs
  - Health and safety
  - Quick-look analysis
Operational Intent of MSAD-MTC

- Two to three 16-day utilization flights each year

- **Operation of facilities during utilization flights**
  - Experiments requiring crew interaction
  - Shorter duration experiments
  - Experiments that are less sensitive to "noisy" acceleration environment

- **Operations between utilization flights (ground-tended periods)**
  - Experiments that can be controlled remotely and/or automated
  - Longer duration experiments
  - Experiments requiring a pristine environment

- **Operations during assembly flights**
  - Conducted on a non-interference basis
  - May be limited to changing out samples and setting up experiments to be initiated later

Operational Intent of MSAD-PMC

- Payloads requiring crew interactions
- Automated payloads utilizing telescience methods
- Crew time is a limited resource
Science return from MSAD payloads will begin in 1997 after launch of the U.S. Laboratory and will continue through 2000+

- MSAD plans to conduct a broad range of experiments during the unmanned periods prior to PMC, during utilization flights, and PMC and beyond on SSF

Science operations conducted during the utilization flights will be similar to Spacelab flights except for the added tasks of collecting and securing of samples, experiment setup for unmanned runs, and rack/module equipment changeout

Unmanned operations will require automation of payloads and telescience but minimal two-way communications between MSAD payloads and the ground is intended

- Active, growing, diverse program
- Areas of research
  - Biotechnology
  - Combustion
  - Fluids Science
  - Fundamental Physics
  - Materials Science
- Continuing to find new experimental possibilities
  - Encouraging science community to participate
  - Soliciting science proposals through NRA's
  - Facilitating their development
- Collaborating with the international science community
  - Sharing use of facilities
- Looking forward to an exciting decade in microgravity research
• Community involvement in the program
  - Four DWG's plus Microgravity Subcommittee to Space Science and Applications Advisory Committee (SSAAC)

• National Academy of Sciences
  - Microgravity Science Committee of the Space Studies Board
    -- Established in 1988
    -- First meeting in 1990
  - Development of long-term strategy for microgravity sciences

• Integrate microgravity initiatives into OSSA program
  - SSAAC review and advice
  - OSSA Strategic Plan
SSB Committee on Microgravity Research
Membership List

Chairperson
William A. Sirignano (6/94)
Dean, School of Engineering
University of California at Irvine
[Combustion]

Franklin D. Lemkey (6/92)
Materials Technology Laboratory
United Technologies Research Center
[Metals]

Thomas A. Steltz (6/94)
Department of Molecular Biophysics
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Case Western Reserve University
[Fluid Flow and Transfer]

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Julia R. Weertman (6/94)
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Cornell University
[Physics]

[Biotechnology]

Membership of Microgravity Science and Applications Subcommittee (MSAS)

Chair: Dudley Saville
Chemical Engineering Department
Princeton University

Exec. Secretary: Roger Crouch
NASA Headquarters
MSAD Chief Scientist

MEMBERS

Gary Gilliland
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Center for Advanced Research in Biotechnology
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Simon Ostrach
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Case Western Reserve University

Alexander Mcpherson
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## Members

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<td>Chairman</td>
<td>Dr. Charles A. Fuller</td>
<td>University of California, Davis</td>
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<td>Executive Secretary</td>
<td>Dr. Edmond M. Reeves</td>
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<td>Dr. Charles E. Bugg</td>
<td>University of Alabama at Birmingham</td>
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<td>Dr. Benton C. Clark</td>
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<td>Dr. Earl L. Cook</td>
<td>3M Corporation</td>
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<td>United Technologies Research Center</td>
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<td>Dr. Marc E. Tischler</td>
<td>University of Arizona</td>
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### Discipline Working Groups

- **Biotechnology**
  - Chair: Dr. Gary Gilliland (NIST)
  - Vice-Chair: Dan Carter (MSFC)

- **Combustion**
  - Chair: Dr. Gerard Faeth (University of Michigan)
  - Vice-Chair: Kurt Sacksteder (LeRC)

- **Fluids and Transport**
  - Chair: Stephen H. Davis (Northwestern University)
  - Vice-Chair: Bob Thomson (LeRC)

- **Materials Science**
  - Chair: John Perepezko (University of Wisconsin)
  - Vice-Chair: Frank Szofran (MSFC)
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CEREM/DEM - Section d'Etudes de la Solidification
et de la Cristallugenesse, Grenoble

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School of Mechanical Engineering
Georgia Institute of Technology

Dr. John Huang
Exxon Research and Engineering Company

Prof. Harry Swinney
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University of Texas at Austin

Prof. Richard Lahey
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ESA Representative
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National Institute of Standards and Technology
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University of Michigan

Mr. Kurt Sacksteder (Vice-Chair)
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Mississippi State University

Prof. Robert Santoro
Mechanical Engineering Dept.
Pennsylvania State University

Dr. Raymond Friedman
Factory Mutual Research

Prof. Mitchell Smooke
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Vice-President for Information Technology
Georgia Institute of Technology

Dr. Robert Santoro
Mechanical Engineering Dept.
Pennsylvania State University

Dr. Gary Gilliland (Chair)
Center for Advanced Research in Biotechnology
National Institute of Standards and Technology

ESRA Representative
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CNRS - Laboratoire de Combustion et Systemes Reactifs, Orleans

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Vice-President for Information Technology
Georgia Institute of Technology

ESRA Representative
Prof. P. G. Pighetti
Universita di Milano, Departmento di Scienze e Tecnologie Biomediche, Sez. Chemica Organica, Milano

Dr. Daniel Carter (Vice-Chair)
NASA Marshall Space Flight Center

Dr. Scott Power
Director of Biochemistry
Genencor International

Dr. Patricia Weber
Central Research and Development Dept.
Dupont-Merck Pharmaceutical Company

Dr. Colette Freeman
Division of Cancer Biology, Diagnosis, and Centers
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Prof. Lola Reid
Dept. of Molecular Pharmacology
Albert Einstein College of Medicine

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Membership of Discipline Working Groups (DWG's)

**DWG**

= 8 - 12 members

- Chair
- Ex Officio Member
- Vice-Chairperson
- 4 Members
- Member

Unaffiliated (desired)
Discipline Program Scientist
Center Scientist
Principal Investigator(s) (2 maximum)
Industry
Academia
Other Government